Effect of DGS Utilization on Characteristics of Square shaped CSRR-Based SIW BPF

Abdul Latip
Department of Electrical Engineering
Faculty of Science and Technology
UIN Sunan Gunung Djati
Bandung, Indonesia
abdullatip1110@gmail.com

Nanang Ismail
Department of Electrical Engineering
Faculty of Science and Technology
UIN Sunan Gunung Djati
Bandung, Indonesia
nanang.is@uinsgd.ac.id

Opik Taupik Kurahman
Department of Informatics Engineering
Faculty of Science and Technology
UIN Sunan Gunung Djati
Bandung, Indonesia
opik@uinsgd.ac.id

Achmad Munir
Radio Telecommunication and Microwave Laboratory
School of Electrical Engineering and Informatics
Institut Teknologi Bandung
Bandung, Indonesia
munir@ieee.org

***Abstract*—This paper discusses the effect of defected ground structure (DGS) utilization on the characteristics of substrate integrated waveguide (SIW) bandpass filter (BPF) made of square shaped complimentary split ring resonator (CSRR). There are 2 pieces of DGS pattern with a round and square pattern made on the groundplane. Meanwhile the CSRR has 2 pairs of patterns consisting of an inner ring and an outer ring. The proposed SIW BPF was designed on a 1.6mm thick FR4 epoxy dielectric substrate with the size of 45mm × 40mm. The filter is designed to have the center frequency of 6.75 GHz with the frequency range from 3 GHz to 15 GHz. The investigated parameters of filter include DGS shape, CSRR dimension, distance between vias, and via diameter. It is found that the utilization of DGS and CSRR could enhance the filter characteristics. The characterization results show that the filter with square DGS patterns has the best performance among others with S_{11} value of –18.44 dB, S_{21} value of –3.01 dB, and fractional bandwidth of 122%.**

***Keywords*—bandpass filter (BPF); complimentary split ring resonator (CSRR); defected ground structure (DGS); substrate integrated waveguide (SIW).**

I. Introduction

As is already well-known that microwaves have an active role in wireless communication technology, one of them is in the field of device development [1]– [2]. Filters as one of electromagnetic devices can limit and allow the desired frequency signal, and reject unwanted frequency signals. There are several methods in developing filters implementable for high frequencies and microwave region including waveguide, dielectric resonator, and microstrip [3]–[4]. The latter aforementioned method is one of the most popular and widely techniques, i.e. microstrip filter, as it could be small in size, inexpensive in cost of implementation, and combinable with other structures and methods, such as photonics band-gap (PBG), defected ground structure (DGS), and substrate integrated waveguide (SIW).

Based on the idea of PBG structure, the DGS which was first introduced in 1999 has been found in the design of planar circuits and lowpass filters [5]. Here, the use of DGS structure aims to disrupt the protective current distribution at the groundplane affecting the characteristics change of transmission line such as capacitance and inductance in order to have a slow-wave and band-stop effect [6]. Meanwhile, for filter application, the DGS structure affects in the rejection of certain frequency or band-gap. Hence, the DGS structure will change the nature of currents flowing in the groundplane of filter by putting one or more patterns in its area [7]–[8]. Moreover, the DGS implementation for microstrip BPF could produce wideband frequency response applicable for ultra-Wideband (UWB) application [9].

Furthermore, the filter design technique which is also frequently used is SIW method [10]. The use of SIW method on the design of filters could accommodate very high-frequency signals which were sometimes balanced with high power handling [11]. The via hole which connected a pair of metal plates made through the dielectric substrate is the basis of SIW structure [11]– [12]. Moreover, instead of only employing DGS and SIW methods, the other structure namely complimentary split ring resonator (CSRR) could be sometimes incorporated into or combined with microstrip filter to achieve optimum result implementable for desired application [7]–[8], [12]. The structure of CSRR is basically obtained by making some patterns on the patch area and usually consists of a pair of closed loops of non-magnetic material in a circle or square with split ends opposite. The structure which is often found in metamaterials deployemnt is aimed to improve the performance of microwave devices as it could produce large capacitance value and strong coupling connection between loops [13]–[15].

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In this paper, the characteristics of SIW BPF which consists of square shaped CSRR structure is investigated as the effect of DGS utilization at the groundplane. The aim of DGS utilization is to improve the filter performances such as enhancing return loss and insertion loss as well as widening bandwidth response. The parameters of filter used for performance investigation include DGS shape, CSRR dimension, distance between vias, and via diameter. Meanwhile, the performances of filter is then optimized by changing the dimension of DGS and CSRR structure. The SIW BPF is designed to have the working bandwidth in the frequency range from 3 GHz to 15 GHz for radar application.

II. Design of Square Shaped CSRR-Based SIW BPF

The configuration of SIW BPF which consists of two square shaped CSRR structures is illustrated in Fig. 1. This SIW BPF uses I/O ports made of microstrip lines with the length of l_p and the width of l_t, whereas the patch with CSRR structures has the patch length of W_p, the patch width of W_t, the outer CSRR size of R_o and the inner CSRR size of R_i. Two square shaped CSRR structures are made symmetrically each other and incorporated on top side of the filter. The SIW parameters are denoted by d_v and S_v for via diameter and distance between vias, respectively. The vias of 18 pieces are also symmetrically configured surrounding the CSRR structures. Meanwhile, the length and the width of dielectric substrate and groundplane are indicated by W_f and l_f, respectively. The filter which is designed on a 1.6mm thick FR4 epoxy dielectric substrate is expected to work at the center frequency of 6.75 GHz in the frequency range from 3 GHz to 15 GHz.

Figs. 2 and 3 illustrate the filter configuration with two circle and square shaped DGS patterns, respectively. Similar to the filter without DGS utilization, the filters with DGS utilization have also the same notation of physical parameters and are also designed using a 1.6mm thick FR4 epoxy dielectric substrate. The performance of filters with DGS utilization is optimized by varying the dimension of DGS from 4mm to 7mm with 0.5mm interval. It is found that the optimization process could produce the best performance result for filter when the dimension of DGS pattern is 7mm. It is noted that the maximum dimension of DGS that could be set is 7mm since the area for DGS is limited by the vias. Table I summarizes the dimension of each parameter for all the filters.

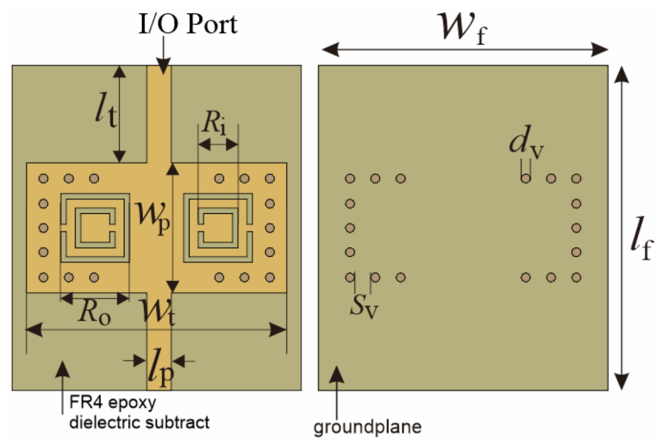

Fig. 1. Configuration of SIW BPF with two square shaped CSRR structures; left side is top view; right side is bottom view.

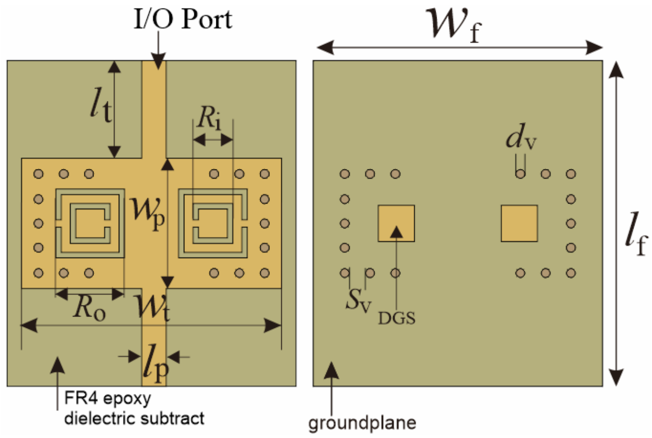

Fig. 2. Configuration of square shaped CSRR-based SIW BPF with two square shaped DGS patterns; left side is top view; right side is bottom view.

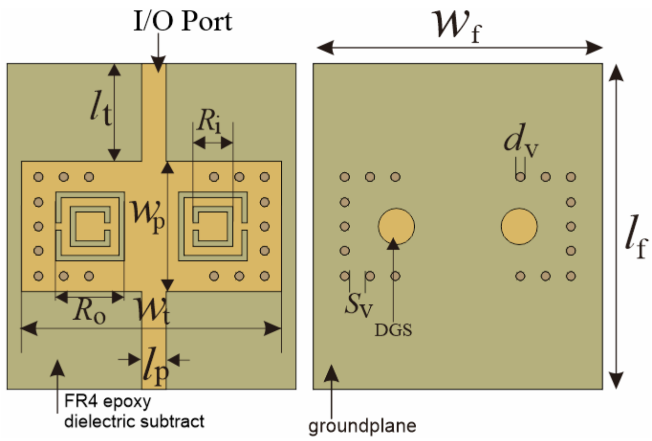

Fig. 3. Configuration of square shaped CSRR-based SIW BPF with two circle shaped DGS patterns; left side is top view; right side is bottom view.

TABLE I
Dimension of Squared Shaped CSRR-Based SIW BPF.

Parameter	W_f	L_f	W_t	W_p	L_t
Dimension (mm)	40	45	36	18	13.5
Parameter	L_p	R_o	R_i	d_v	S_v
Dimension (mm)	3.4	9.5	5.5	3.5	1.2

III. Realization and Characterization

Based on the optimization results, the filters are realized using wet etching technique on a 1.6mm thick FR4 epoxy dielectric substrate with the relative permittivity of 4.3. Each realized square shaped CSRR-based SIW BPF is equipped with two SMA connectors connected at the input and output ports for experimental characterization. The vias which use

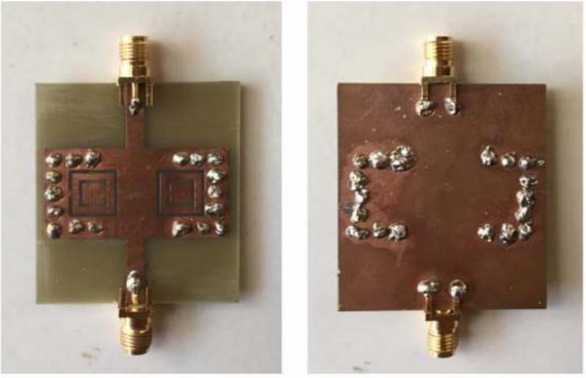

Fig. 4. Realized SIW BPF with two square shaped CSRR structures; left side is top view; right side is bottom view.

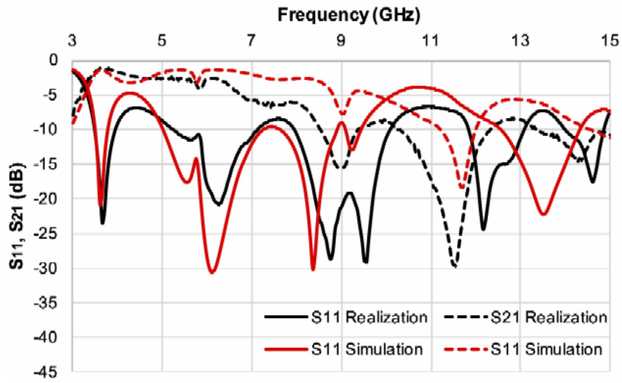

Fig. 7. Measured and simulated results for SIW BPF with two square shaped CSRR structures.

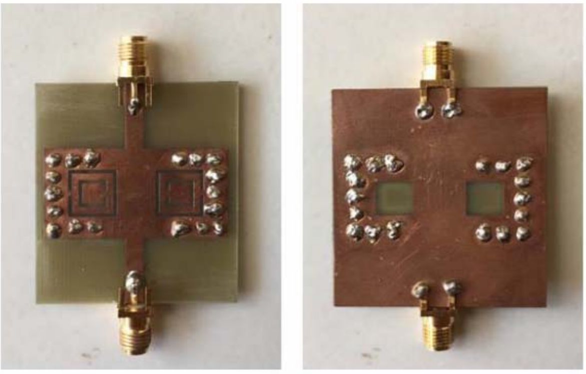

Fig. 5. Realized square shaped CSRR-based SIW BPF with two square shaped DGS patterns; left side is top view; right side is bottom view.

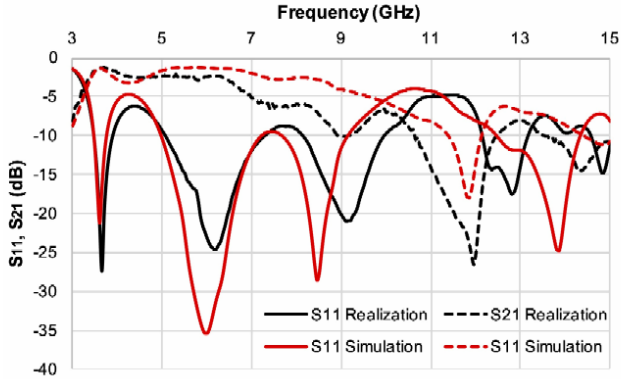

Fig. 8. Measured and simulated results for square shaped CSRR-based SIW BPF with two square shaped DGS patterns.

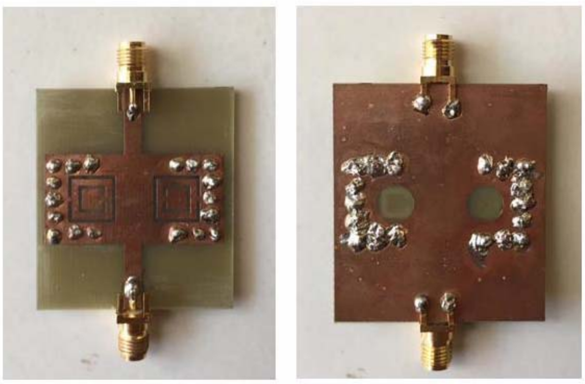

Fig. 6. Realized square shaped CSRR-based SIW BPF with two circle shaped DGS patterns; left side is top view; right side is bottom view.

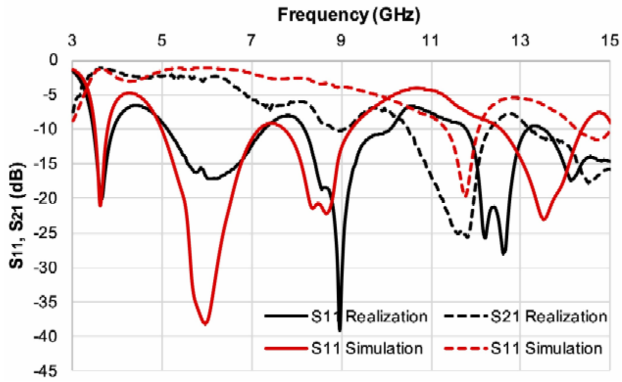

Fig. 9. Measured and simulated results for square shaped CSRR-based SIW BPF with two circle shaped DGS patterns.

copper conductor wires with the diameter of 1.2mm are installed, while the both ends of vias are soldered with the patch on the top side and the groundplane on the bottom side. Figs. 4–6 show the realized filter without DGS utilization, with two circle shaped DGS patterns, and with two square shaped DGS patterns, respectively.

Measurement results for the SIW BPF with two square shaped CSRR structures are plotted in Fig. 7 with the simulation results plotted together as comparison. It shows that the measured results have the frequency shift, and the decrease of S_{11} and S_{21} but with wider working bandwidth which achieved 121% fractional bandwidth. The simulations have S_{11} value of –15.22 dB, S_{21} value of –2.33 dB, and working bandwidth of 6.7 GHz. While the measured results have S_{11} value of –11.36 dB, S_{21} value of –3.02 dB, and working bandwidth of 6.9 GHz.

Fig. 8 shows measured and simulated results for the square shaped CSRR-based SIW BPF with two square shaped DGS patterns. Similar to the filter without DGS pattern, some discrepancies occurred in terms of frequency response, S_{11} and S_{21} values, and working bandwidth. The simulated results have attained S_{11} value of –32.76 dB, S_{21} value of –1.27 dB, and working bandwidth of 6.6 GHz. Meanwhile the measurements have S_{11} value of –18.44 dB, S_{21} value of –3.01 dB, and working bandwidth of 7.1 GHz. The fractional bandwidth for the square shaped CSRR-based SIW BPF with two circle shaped DGS patterns is around 122%.

The comparison between measurement and simulation results for the square shaped CSRR-based SIW BPF with two circle shaped DGS patterns is depicted in Fig. 9. Here, some differences in the result of measurement and simulation also occurred. The simulation could achieve S_{11} value of –35.45 dB, S_{21} value of –1.27 dB, and working bandwidth of 6.7 GHz. Whilst the measured results have S_{11} value of –16.28 dB, S_{21} value of –2.77 dB, and working bandwidth of 7 GHz or its fractional bandwidth is 121.7%.

From all the results, it can be inferred that the DGS utilization has significant effect to the characteristics of square shaped CSRR-based SIW BPF. It could also be noted that the square shaped CSRR-based SIW BPF with two square shaped DGS patterns has the best performance among others demonstrating the effectiveness of such DGS patterns in enhancing the characteristics of filter.

IV. Conclusion

The effect of DGS utilization on the characteristics of SIW BPF composed of square shaped CSRR has been investigated. The square shaped CSRR-based SIW BPF with and without DGS patterns have been designed and realized on a 1.6mm thick FR4 epoxy dielectric substrate. It has been shown that the DGS utilization has significant effect in improving the characteristics of square shaped CSRR-based SIW BPF. In addition, the choice of DGS pattern as well as its dimension has also hold an important role in effectively enhancing characteristics of the filter.

Acknowledgment

The authors would like to thank the manager and technicians of Radio Telecommunication and Microwave Laboratory and Microwave, School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Indonesia for the opportunity to utilize the research facilities, and the Research and Publishing Center of Universitas Islam Negeri (UIN) Sunan Gunung Djati Bandung, Indonesia for sponsoring the current research and its publication.

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